Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Investigating the Static and Dynamic behavior of a Novel 3D Foldable-Twistable Metastructure: Mathematical, Simulation, and Experimental Analysis

Siros Khorshidi[1], Zia Saadatnia[1,2*]
[1]Department of Mechanical and Manufacturing Engineering, Ontario Tech University, Oshawa, Canada
[2]Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, Canada
*zia.saadatnia@ontariotechu.ca

ABSTRACT

Mechanical metamaterials or meta-structures, renowned for their exceptional mechanical properties, have gained considerable attention in recent years. These properties, which stem from the unique architecture of their structural composition rather than their intrinsic material composition, include programmable stiffness, negative Poisson's ratio, and tunable compressibility. This study investigates the static characteristics and dynamic response of a novel 3D foldable-twistable meta-structure. With incorporating compression-torsion coupling effect, a unique geometry of the structure is designed. Using energy method and Lagrange principles, a comprehensive mechanics model for finding static and dynamic characteristics of the system is derived. To understand the structure's static behavior, the force-displacement curve, Poisson's ratio, and Young's modulus are analyzed to explore the stiffening and auxetic behavior as a function of various geometrical parameters. The study also examines the dynamic response of the developed structure including softening-hardening and vibration level difference versus frequency. In addition to mathematical modeling, finite element (FE) simulations, and experimental characterizations are performed to validate the findings. The results prove that the structure exhibit evidence of nonlinearity which can be utilized in various applications including energy absorption, vibration control, and energy harvesting.